Global Modeling of Surface Boundary Forcing

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From a climate dynamics perspective, water-related processes are the key links between ocean, atmosphere, and land biosphere components. Thus, in order to develop a predictive capability for anticipating variability or change in climate, either locally or in a global sense, an improved physical basis for linking the hydrologic and energy cycles in climate models has high priority. MSFC is continuing its joint investigation with Pennsylvania State University and the National Center for Atmospheric Research in using the GENESIS Earth System model to study short-term climate variability. The team has approached this problem on two fronts: (1) using existing data sets emerging from the Pathfinder effort to critique and validate the hydrologic cycle of GENESIS model versions, and (2) performing sensitivity experiments to have a better understanding of the linkages between ocean, atmosphere, and land biosphere subsystems, particularly with respect to replicating recent short-term climate anomalies, such as El Niño/Southern Oscillation events.

The effort's experimental strategy has initially involved a series of 10-year model integrations based on the Department of Energy's Atmospheric Model Intercomparison Project format. This involves specifying observed sea-surface temperature values as lower boundary forcing and performing an additional control integration forced with seasonally varying sea-surface temperatures. Initial experiments were done at R12 (5.0 by 7.0 degrees) horizontal spatial resolution; the more recent model version, GENESIS 2.0, uses T31 (3.75 by 3.75 degrees). Results to date have clarified the nature of the predictability problem for interannual climate variations: (1) tropical sea-surface temperature forcing has a robust quasilinear response in the vicinity of the heating (rainfall, divergent circulations, and radiative anomalies associated with the 1982 to 1983 and 1986 to 1987 El Niño/Southern Oscillation events are captured reasonably well); (2) far-field, middle-latitude response is characterized by a much lower signal-to-noise ratio, due in large measure to the natural variability inherent in higher latitude baroclinic flow; and (3) warm-season, middle-latitude anomalies, such as the 1988 drought over the United States in early summer, show signs of significant predictability.

Our most important and recent result from GENESIS 2.0 comparing 1985 to 1989 gives evidence of positive water-vapor feedback averaged over the tropical oceans (30 °N to 30 °S) in association with elevated sea-surface temperatures.
Figure 13 shows two curves depicting the outgoing longwave radiation at the top of the Earth's atmosphere for this region. The solid curve is the value measured by the Earth Radiation Budget Satellite and includes a mixture of radiative effects from moisture and temperature anomalies. We have few good direct measurements of water vapor, but we can calculate the effects of sea-surface atmospheric temperature variations on the radiation quite well (dotted line). The difference in these two curves is the effect that changes in water vapor have on the longwave radiation leaving the planet. Analysis has shown that for an increase in 1 Kelvin in sea-surface temperature, the water-vapor trapping of terrestrial radiation increases by about 2 watts per square meter. A similar result has been found for the GENESIS model. This kind of study is helping us understand the role that deep tropical convection might play in future climate change through its effect on the atmospheric water-vapor field.

Recent availability of the International Satellite Land Surface Climatology Project data set, observed precipitation, and satellite estimates of surface-incident solar radiation (plus other data) now permit the global diagnosis of a soil-moisture time series with reasonably accurate observational constraints. Scientists have begun an integration in which the observed precipitation and incident solar radiation are used in lieu of the corresponding GENESIS fields to force the model land-surface package, thus synthesizing an "observed" soil-moisture field analogous to the observed sea-surface temperatures.

For the longer term, the research team plans to test a coupled modeling system involving GENESIS and nested regional models having land surface and hydrologic components. This coupled, nested system will be evaluated for its ability to translate anomalous sea-surface temperatures

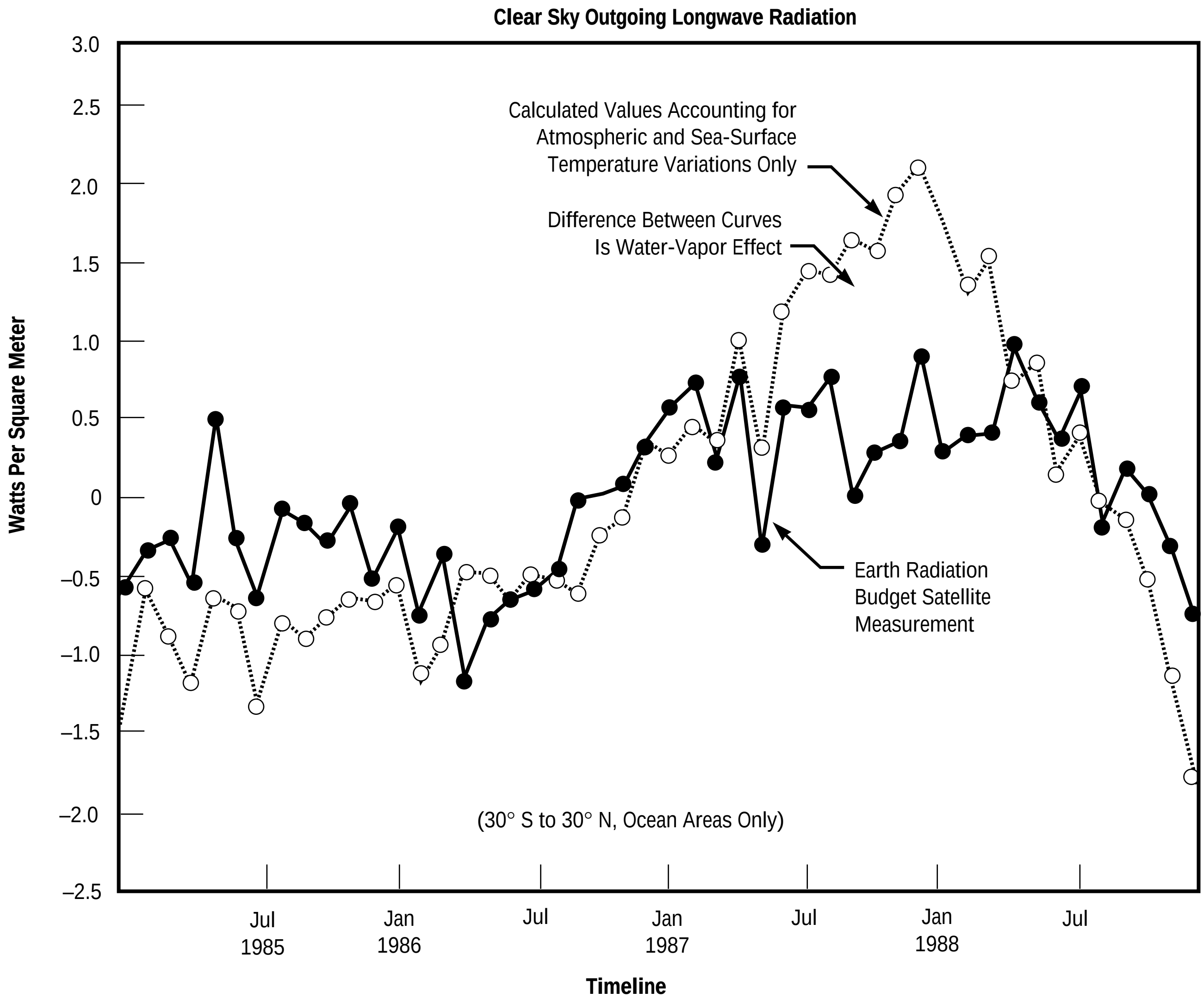

FIGURE 13.—Earth radiation satellite diagnostics of positive water-vapor feedback.

and land-surface forcing into regional and local hydrologic changes. Collectively, these findings will illustrate the mechanisms by which hydrology, radiation, and dynamics are involved in climate variability.

Sponsor: Office of Mission to Planet Earth

University Involvement: Pennsylvania State University

Other Involvement: National Center for Atmospheric Research